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CHEMICALS FOR BRUSH CONTROL IN CALIFORNIA REFORESTATION

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ABSTRACT: This report summarizes findings from experimental trials with selective herbicides applied to forest shrubs and trees in California and adjacent regions. It also recommends formulations and amounts to apply to various species.

Brush forms a major obstacle to reforestation in California. It can deplete soil moisture, provide protective cover for destructive rodents, and impede tree growth. On cleared sites, brush quickly resprouts and reseeds. It competes with newly planted trees and established young growth.

Almost all woody shrub species in the commercial timber zone of California produce large quantities of seeds. Some seeds retain their viability for years and then germinate when exposed to favorable conditions (Quick, 1956, 1959). Many of the more common species sprout from stumps and roots after their aerial parts have been killed (Bruce, 1939; Dunning and Kirk, 1939; Leonard and Harvey, 1956; Roy, 1955; Schubert, 1950, 1955).

Foresters are always seeking more effective methods of controlling brush in planting site preparation and in the release of established trees. Chemicals for brush control have won increasing attention because they show promise in a large number of experiments.

This paper summarizes findings in the literature on the use of chemicals in planting site preparation and reports the results of Station tests of selective herbicides for release of established trees. Although the Station experiments are chiefly small-scale trials, they produced

information which may be useful in operational size jobs. Some preliminary recommendations, based on the author's interpretation of these and previously published results, are tabulated as a rough guide to operational decisions.

PLANTING SITE PREPARATION

Competing brush can be killed by mechanical means, such as clearing land with a tractor, or by chemicals used alone or in combination with other measures. If an area is to be burned, the effectiveness of the fire can be increased either by crushing the brush with a tractor or by killing the brush with chemicals. Planned burning will probably not be widely used either with or without chemical pretreatment because of the serious risk associated with prescribed burning in California. Spraying brush before mechanical eradication serves no useful purpose.

After viable brush seeds have germinated, followup chemical treatment may be applied either before or after tree planting. Some evidence indicates that shade from brush benefits the initial establishment of trees (Dahms, 1950; Show, 1924, 1930); however, brush competion is generally harmful after trees are established (Tackle and Roy, 1953). Tarrant (1957, 1958) found that the soil moisture on plots with cleared or dead brush remained above the wilting point in central Oregon, whereas under live shrubs the moisture content had dropped below the wilting point at the 10-14-inch and 20-24-inch depths before the first fall rain in September. Brush should be sprayed before it becomes increasingly resistant to chemical treatment and before it becomes a serious fire hazard when killed.

Experience in killing brush with chemicals for planting site preparation in California has been limited mainly to experimental trials. Most of the tests have been applied selectively to individual plants rather than on an area basis.

Many chemicals have been tested as brush killers in western forest areas (Bruce, 1939; Cox and Ritchie, 1960; Dahms, 1955, 1961; Gratkowski, 1959, 1961; Leonard and Harvey, 1956; Offord, 1949; Offord, Quick, and Moss, 1958; Roy, 1956; Schubert, 1950, 1955). Of all the chemicals tried the herbicides 2,4-D and 2,4,5-T have been the most extensively tested and widely used. The low volatile ether esters of these two herbicides have been generally favored because they have given consistently good results on woody plants and minimized risks of damaging crop plants near treated areas (Dahms, 1955, 1961; Gratkowski, 1959, 1961; Leonard and Harvey, 1956).

In these tests, some brush species were easily killed by low rates of application regardless of when plants were treated. Others showed no appreciable kill under the conditions tested in some areas and good kill under other conditions. Relatively few tests used more than one rate or more than one spray date.

Many researchers have attempted to identify the field conditions that will result in optimum kill of brush, recognizing that stage of plant development, soil and climatic environment, species of plant, and even time of day when sprays are applied would have to be evaluated (Dahms and James, 1955; Gratkowski, 1959; Leonard and Harvey, 1956; Offord, 1949, 1958; Schubert, 1950, 1955). In small trials with Sierra evergreen chinkapin in California, the author obtained best results with early morning treatment with 2,4,5-T. Early morning and late afternoon treatments with 2,4-D gave better kill than mid-day work but were not as effective as the early morning sprays with 2,4,5-T. Where mixed species of brush are concerned, it will always be necessary to make a practical compromise on when and how to treat.

Foliage sprays usually provide the most effective control of brush. On undesirable hardwood trees, however, better kill has been attained by applying the chemicals to cut stumps or in frills. Enough solution should be applied per tree to fill the frill of the completely girdled trunk near the root crown. Roy (1956) found that the effects of the herbicide in frills was delayed, but the vigor of treated trees decreased more the third and fourth years than that of trees which received a basal spray. Bruce (1939) reported a 95 percent kill on live oak stumps treated with a 10 percent aqueous solution of sodium chlorate. With a 1 percent solution of 2,4-D, Schubert (1950) found that madrone proved easier to kill than tanoak. The midsummer treatment was best on madrone and the fall treatment for tanoak.

For hard-to-kill species the addition of a gallon of light summer oil per acre (Dahms, 1961) or about 5 percent by volume of diesel oil (Gratkowski, 1959) has increased the kill in Oregon. Leonard (1961) reported that the addition of some oil to spray mixtures increased the kill. The amount of oil (either kerosene or diesel oil) to be added should normally not exceed 1 percent or 1 gallon per acre for California brush species. Schubert (1955) found that adding wetting agents or emulsifiers did not increase the effectiveness of sprays appreciably.

Gratkowshi (1961) found that a combination treatment of spray-burn-spray gave good results in Oregon. In July, 1955, an 80-acre brushfield composed mainly of greenleaf manzanita and mountain whitethorn ceanothus was sprayed with 2,4-D at a rate of 3 pounds acid plus 1.5 gallons diesel oil per acre. Almost every species resprouted. In late September 1956, the brush was burned. Extensive resprouting occurred again, along with about 10,000 new brush seedlings per acre. A respray in 1958 killed about 90 percent of the new brush. A second respray in 1959 destroyed almost all the remaining brush on the area.

Herbicide treatments suggested for common brush or hardwood species in California are listed in table 1. These suggestions are based on interpretation of results from the studies cited, and readers who wish more detailed information should consult the publications. Because the suggested

treatments are interpretations, the data in table 1 may differ from the published results. An asterisk (*) in the table indicates that treatment and expected results are mainly a "best estimate" in this author's opinion.

Nonsprouting species, labeled (N) in table 1, are generally killed with one spray treatment. Many sprouters, labeled (S), may require two or more treatments to obtain satisfactory kill.

The best time to spray has not been determined for all brush species. Where both spring and fall periods have been included, the fall months have usually given the best results. Brush should not be sprayed when the temperature drops below 36°F.

The water miscible, low-volatile ether ester form of the suggested herbicide should be used. Examples include propylene glycol butyl ether ester and butoxy ethanol ester.

Rate refers to pounds of active material. For aerial application, 5 to 10 gallons of solution per acre have given good results. For hand or power sprayers 50 to 150 gallons per acre are needed to get good coverage depending on height and density of the brush. One gallon of light summer oil or diesel oil per acre should be added to get better kill where no conifers are involved. If conifers are present and are to be saved, not more than 1 lb./A of 2,4,5-T should be used; 2,4-D can be substituted for Douglas-fir areas. To kill undesirable hardwood trees, 1 gallon of herbicide (4 pounds acid equivalent) should be used to 10 or 12 gallons of low grade diesel oil or 1 gallon oil plus 10 gallons of water. Enough solution should be applied per tree to fill the frill of the completely girdled trunk near the root crown.

The amount of kill shown in the table indicates the percent top kill (100/) and the percent root kill (/100) based on best kill obtained. Where top or root kill is less than 100 percent, the brush should be re-treated if a heavier kill is needed.

RELEASE OF ESTABLISHED TREES

TESTS AT STANISLAUS

One of the more important uses of selective herbicides in the future may be to release young trees from competing brush. A small-scale test[1/] on the Stanislaus Experimental Forest in California indicated that young sugar pines could be safely sprayed with low volatile ester of 2,4-D and 2,4,5-T in spring before the start of growth and in fall after top growth had been completed (table 2). Twenty trees growing in clumps of mountain whitethorn ceanothus were treated with 2,4-D and 2,4,5-T in each of eight months. Each tree-brush clump was drenched with a mist spray at the rate

1/ Methods and findings pertaining to these tests will be published elsewhere in greater detail.

of 200 lb./A of acid in water. Trees sprayed during the growing period were damaged more severely by 2,4-D than by 2,4,5-T. The damage was restricted mainly to the new growth on both terminal and lateral shoots.

In another study, young sugar pines treated with 2,4,5-T in water at dosages of 1/4 to 1 pound acid per acre showed no serious damage, but rates of 2 and 4 pounds acid per acre resulted in higher mortality and reduced growth. Six 1/10-acre plots of sugar pines in dense mountain whitethorn were sprayed on September 24, 1959. Four of the plots had some ponderosa pines and incense-cedars. Most trees were as tall or slightly taller than the brush. None of the incense-cedars was killed. The amount of first-year kill for the pines and mountain whitethorn was:

Herbicide (Rate, lb./A)	Sugar pine	Ponderosa pine	Mountain whitethorn
	(Percent)		
1/4	0	0	0
1/2	0	0	25
1	4	--	50
2	15	--	60
4	55	75	80

The average growth of the living trees during the first growing season after treatment was:

2,4,5-T (Rate, lb./A)	Sugar pine	Ponderosa pine	Incense-cedar
	(Inches)		
0	4.3	6.7	3.1
1/4	6.5	9.8	2.4
1/2	3.8	3.1	2.2
1	2.5	--	--
2	-2.2	--	--
4	-4.8	-5.7	-9.1

OTHER STUDIES

Older ponderosa and Jeffrey pines in a manzanita brushfield at Mount Shasta showed damage when treated with 2,4-D and 2,4,5-T during the growing period.[2/] They revealed little to no damage when sprayed early in the spring or in September even at a rate of 4 pounds per acre.

In Oregon, ponderosa pines fully exposed to sprays of 2,4-D at rates of 2 pounds or more acid per acre were completely killed or nearly so, but a 1-pound rate caused only slight damage (Dahms, 1955). Dahms (1961) later found that ponderosa pine can tolerate about twice as much 2,4,5-T as 2,4-D and about twice as much of either chemical in water as in an

2/ Methods and findings pertaining to the test on manzanita brushfield at Mount Shasta will be published elsewhere in greater detail.

emulsion (1 gallon summer oil per acre). Tolerance of these trees to the two herbicides varied with season. Treatments in July did the most damage to terminal buds, and spraying in late September did the least damage.

Dahms (1955) has also indicated that Douglas-fir, lodgepole pine, Port-Orford-cedar, western white pine, grand and white firs, and Sitka spruce could be treated at a rate of 1 pound acid per acre of 2,4,5-T without serious damage. The propylene glycol butyl ether esters of 2,4,5-T were reported to cause less damage than butoxy ethanol esters (Krygier, 1961). Gratkowski (1961) found that Douglas-fir was more resistant than sugar and ponderosa pines to 2,4-D and 2,4,5-T. In his study, Douglas-fir was about equally resistant to both chemicals. Since a number of brush or hardwood species commonly associated with Douglas-fir are more susceptible to 2,4-D, this herbicide may be used where Douglas-firs are to be released from competition with tanoak and madrone.

Brushfields of easily killed species which are stocked with suppressed conifers can be treated with low concentrations of 2,4-D and 2,4,5-T to release the trees. For release of conifers the entire brush need not be killed. The herbicides should be applied in spring before tree growth starts or in fall when the trees are dormant. The rates should not exceed 1 pound of acid per acre and 1/2 to 3/4 lb./A may be preferable.

Table 1.--Herbicide treatment for common brush or hardwood species in California

Plant species	Time to treat	Herbicide	Rate lb./A	Kill	Authority[1/]
Bearmat (S) *Chamaebatia foliolosa*	Sept.-Nov. March-May	2,4-D or 2,4-D + 2,4,5-T	8	100/80-95	(3, 23)
Big sagebrush (S) *Artemisia tridentata*	April-June	2,4-D	2	100/100	(4, 11, 15)
Bigleaf maple (S) *Acer macrophyllum*	May-June	2,4,5-T	4	100/ ?	(15)
Bitter cherry (S) *Prunus emarginata*	Aug.-Oct. March-April	2,4,5-T or 2,4-D + 2,4,5-T	4	100/90	(2)*
Blueblossom ceanothus (N) Ceanothus thyrsiflorus	Aug.-Oct. March-April	2,4-D or 2,4,5-T	2	100/100	(15)
Bracken fern (S) *Pteridium*	June-July	2,4,5-T	1	100/90	*
California black oak (S) *Quercus kelloggii*	Oct.-April	2,4,5-T or 2,4,5-T + 2,4-D	4	90/50-90	(15)*
Chamise (S) *Adenostoma*	Nov.-June	2,4-D	3	90/80	(2, 14, 15)
Chokecherry (S) *Prunus*	May-June Aug.-Oct.	2,4,5-T	4	100/90	*
Currant (S) *Ribes*	May-June	2,4,5-T	2	100/90-100	(17)

NOTE: See Footnote at end of table.

Table 1.--Continued

Plant species	Time to treat	Herbicide	Rate lb./A	Kill	Authority[1/]
Deerbrush ceanothus (S) *Ceanothus integerrimus*	July-Oct. April-May	2,4,5-T or 2,4-D	2	100/70-90	(12)
Golden chinkapin (S) *Castanopsis chrysophylla*	June-July (April, Sept.-Nov.)	2,4,5-T	4	60/0 ?	(12)* (11)
Gooseberry (S) *Ribes*	May-June	2,4,5-T	2	100/90-100	(17)
Greenleaf manzanita (S) *Arctostaphylos patula*	Sept.-Oct. April-May	2,4-D (Fall) 2,4,5-T (Spring)	2	100/90-100	(23)
Hairy manzanita (N) *Arctostaphylos columbiana*	June-July	2,4-D or 2,4,5-T	1-2	100/100	(12)
Littleleaf ceanothus (N) *Ceanothus parvifolius*	April-Nov.	2,4,5-T	1	100/100	(23)
Madrone (S) *Arbutus*	June-July	2,4-D or 2,4-D + 2,4,5-T	4	100/28	(22)
Mariposa manzanita (N) *Arctostaphylos mariposa*	May-June	2,4-D	2	100/100(?)	(14)
Mountain whitethorn ceanothus (S) *Ceanothus cordulatus*	April-May Sept.-Nov.	2,4,5-T	2	Old plants 100/20 Young sprouts 100/80	(23)

NOTE: See footnote at end of table.

Table 1.--Continued

Plant species	Time to treat	Herbicide	Rate lb./A	Kill	Authority[1/]
Parry manzanita (N) *Arctostophylos parryana*	April-June	2,4-D or 2,4,5-T	2	100/100	(5, 7)
Poison-oak (S) *Toxicodendron quercifolium*	May-June	2,4-D + 2,4,5-T	2	100/90	(15)
Rabbitbrush (S) *Chrysothamnus*	May-June	2,4-D	2	100/100(?)	(11)
Salal (S) *Gaultheria shallon*	May-June Sept.-Oct.	2,4-D + 2,4,5-T	2	?	*
Scotch broom (S) *Cytisus scoparius*	Aug.-Oct.	2,4-D	2	100/90(?)	(15)
Serviceberry (S) *Amelanchier*	July-Sept.	2,4,5-T	2	100/80	*
Sierra evergreen chinkapin (S) *Castanopsis chrysophylla*	Sept.-Nov.	2,4,5-T	8	old 100/20 Young 100/60	(5,23)
Snowbrush ceanothus (S) *Ceanothus velutinus*	April-June Aug.-Oct.	2,4,5-T or 2,4-D	2	100/50	(7, 12)
Squawcarpet ceanothus (S) *Ceanothus prostratus*	Sept.-Nov. March-May	2,4,5-T 2,4-D + 2,4,5-T	2	100/90	(15)

NOTE: See footnote at end of table.

Table 1.--Continued

Plant species	Time to treat	Herbicide	Rate lb./A	Kill	Authority[1]
Tanoak (S) *Lithocarpus densiflorus*	Sept.-Nov.	2,4-D, 2,4,5-T or 2,4-D + 2,4,5-T	4	Trees 65/30 Sprouts 100/100	(21, 22)
Whiteleaf manzanita (N) *Arctostaphylos viscida*	Sept.-Nov. April-May	2,4-D	2	100/100	*
Willow (S) *Salix*	July-Sept.	2,4-D	2	100/80(?)	(15)

1/ Numbers refer to Literature Cited at end of report.

Table 2.--Effect of 2,4-D and 2,4,5-T on young sugar pines growing in clumps of mountain whitethorn, by month of application

Year and month	Average damage rating[1/]			
	Trees		Brush	
	2,4-D	2,4,5-T	2,4-D	2,4,5-T
1958				
July	2.2	2.4	1.4	3.6
August	1.6	0.2	2.0	3.2
September	0.2	0.0	1.8	2.4
October	0.0	0.2	0.4	3.2
November	2.6	0.0	2.0	1.2
1959				
April	0.0	0.0	0.0	3.0
May	2.5	0.4	3.2	4.0
June	2.6	1.6	3.0	3.2

1/ 0 = none; 1 = slight; 2 = moderate; 3 = severe; 4 = killed.

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